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Case Study: The Farming Subdivision as a Concept to Change Non-engineering Majors' Perception of Engineering

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Introduction

Students graduating from high schools, like the general public, usually have a narrow perspective of the engineering profession. This narrow perspective limits their understanding of the contributions engineers make to solving society's complex problems (English, Hudson, Dawes, 2011; Bowen, Prior, Lloyd, Thomas, & Newman-Ford, 2007; Knight & Cunningham, 2004). Often students believe that engineers only deal with the world of mathematics and science and are not concerned with topics commonly taught in the social sciences and humanities. The literature has numerous studies (e.g. Foutz, Navarro, Hill, Thompson, Miller & Riddleberger, 2011) which help students understand that engineers must engage content from multiple, often considered disparate, disciplines to solve societal problems. This understanding shapes how students identify engineering as a potential college major. Foutz et al. (2015) reports a study investigating if integrative learning modules could help recently graduated high school students understand that engineers needed to know more than math and science. This manuscript reports preliminary findings from a study investigating if an agricultural-based case study has a similar impact students' perceptions of the engineering profession.

The University of Georgia requires all incoming first-year students to enroll in a course called the First-Year Odyssey Seminar. Over 300 sections of this course are offered in the fall semester to over 5000 new undergraduates. Each section is taught by a tenured or tenure-track faculty member. Each faculty member may choose the educational subject taught in her/his particular section as long as the faculty member has expertise on the subject. Each of the entering first-year students must enrolled in a First Year Odyssey (FYOS) section, however, the selection of the section is up to the student. Given that most of these incoming first-year students had been a high school student 12 weeks earlier, the First-Year Odyssey Seminar courses offered an excellent opportunity to assess the perception that recently graduated high school students have about engineering. [*Students graduate from high school in late May and enter college in early August*].

The author of this manuscript taught an FYOS course section "Engineering Is Part of a Liberal Education" where the learning objectives were to help students understand that developing solutions to complex problems require the integrative nature of engineering. In this course section, lectures focused on a case study that will be called herein as the Farming Subdivision. The following outlines the case study.

> *Urban sprawl from the Atlanta-metro area is a concern of Jackson County Georgia. In 2002, agricultural census data indicated that the county has approximately 42,000 acres in field crops and this dropped to just over 24,000 acres in 2007 with almost all of this change occurring on the western 1/3 portion of the county. The eastern half of the county remained rural, and agribusiness was the primary business. Taking advantage of this situation, a local developer designed a subdivision adjacent to an active dairy farm where the residents of the subdivision could use part of the farm for gardening and could purchase milk and produce from the farmer.*

Ten first-year first-semester students who enrolled in this FYOS course were asked to use this case study and develop hypothetical Farming Subdivision. The Farming Subdivision was to be a large single-family housing community where the residents became the actual owners and

operators of a farming operation. The students investigated the social, economic, environmental and technical aspects of both the farm and residential housing, including the impact this Farming Subdivision had on local businesses and the health benefits of this concept. Out-of-the-classroom assignments required the students to research different challenges and then discuss their findings in class. All classroom activities, including lecture, and all tasks were guided by the principles outlined in Table 1. More details on these principles are provided in Navarro et al. (2016).

Students in this FYOS section were majoring in political science (1 student), risk management (1), exercise science (1), advertising (1), computer science (2), and psychology (1). Three other students were considering a major in engineering but were classified as an intended-majors (that is, the students had not declared a major) while enrolled in the course. Again, these students had graduated approximately 12 weeks before enrolling in this course, and it was their first semester in college.

Experimental approach

This study's procedures were approved by the Institutional Review Board (IRB), the University of Georgia research oversight committee responsible for ensuring human subject research is conducted in compliance with the applicable federal, state and institutional policies and procedures. Students enrolled in multiple sections of the FYOS course completed surveys assessing their perception of engineering, but only the responses from students who consented to take part in this investigation are included in the analysis reported in this manuscript.

Survey data

The students in the "Engineering Is Part of a Liberal Education" FYOS course were considered to be the TEST group. These students were required to complete a survey designed to assess their perception of engineering program of study. The TEST group completed a survey during the first and last week of the semester. For comparison purposes, students enrolled in another three FYOS sections completed this same survey during the first week of the semester. Topics taught in these three FYOS sections focused on 1) the threshold of democracy in Athens, 2) world hunger and poverty, and 3) US-China business relationships. These three sections did not engage in activities directly related to engineering. Responses from these students were used to assess if the TEST group students had perceptions typical of entering first-year students.

The survey was designed around a storyline describing the Southeastern USA 2006-09 drought and how that drought impacted university students living in dorms. A brief summary of this description follows:

> A severe drought lasting from 2006 to 2009 required the City of Athens, and the University the student attended, to implement level 4 water restrictions which included no outside watering by any resident, business or agency. Even with this restriction, the reservoir that serves Athens reached a critical level where businesses could not provide water unless requested and residents were asked to reduce the amount of bathroom water used. The reservoir came within one day of having no usable water supply, and the student's university came close to shutting off the water supply to all dormitories. Luckily, a substantial rainfall

event avoided this situation. Anticipating future droughts, City and University administrators asked local engineering firms to develop a plan to reduce the amount of water used by businesses in the area and the dorms serving the students at your university. These plans are to be implemented by the year 2020. Failure to implement these technologies results in stiff financial fines.

After reading this description, the students answered questions outlined in Table 2. These questions were designed to assess how the students viewed engineering as a program of study. It is noted the survey was not evaluated for repeatability.

Results

Tables 3 and 4 provide a summary of the TEST group students' responses to the survey taken during the first week of the semester. Responses from the TEST group were not statistically different from the responses made by students in the other three course sections. Table 3 shows that student perception of the difficulty of various courses did not change significantly between the first and end of the semester. The students investigating the Farming Subdivision case study were in their first semester at the university, so the learning activities in this FYOS course section were based on the curriculum commonly found in high school and not on college-level courses. Therefore, it is not surprising that the responses were unchanged during the semester. Some of the students' responses, regarding words that characterize an engineer, did change over the course of the semester (Table 5). Due to the nature of the Farming Subdivision and the activities assigned to the students, these changes were anticipated and are similar to those reported in Foutz et al. (2015).

Table 6 and 7 provide the responses focused on the level of technology an engineer needs to address the water restrictions outlined in the survey's story about the drought. These results in indicate that the students' perception changed more toward non-engineering subjects than those related to technology. As shown in Table 1, most of the activities used to guide the students during their assignments focus on understanding the culture of communities impacted by the problem and the solution. Therefore, it is surprising to find that at the end of the semester, more students indicated that anthropology was not an important knowledge area for the dought situation outlined in the survey. However, this result conflicts with the response that history; the number of students who thought history was important increased by the end of the semester. These results may suggest that the students, as recent high school graduates, may be more familiar with history than anthropology, as an area of knowledge; however, there is not data collected in this study that supporting this suggestion. Further investigation is needed.

Overall, the survey indicates that the learning objectives of the Farming Subdivision may not have been as effective as desired. The study involved only ten students who were from diverse backgrounds and majors; three of the students had not decided on a major while taking the course. This variability in students' background could have influenced their approach to engaging course activities. For instance, the student majoring in psychology may intuitively adopt a humanistic approach to situations whereas the three students majoring in business-oriented majors may have focused more on economics aspects of the Farming Subdivision. These differences could determine how they linked course content to their preconceptions of

the problem. This study needs to be repeated to overcome some of the study's current limitations. However, the preliminary results do suggest that this approach could be useful to help new college students understand the integrative nature of engineering and gain a better perception of the profession.

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Table 1. Essential Elements of Process, Analysis, and Activities that help students integrate knowledge needed to solve complex problems. (from Navarro et al., 2016)

Essential Elements of Process

- Determine the social dimensions of the problem(s)
  - What are the operations of the social units (origins, evolutions, & uncertainties)
  - What are the interactions between social units and the patterns of these interactions
  - What are the historical events of the social units
- Consider the multiple dimensions of the social units
  - What are the multi-dimensional historic perspectives and conditions that affect problem
  - What are the diversity in ethics among the social units/populations
- Various conditions of problems
  - What are the conditions and potential conditions that affect future behavior, characteristics, & functions of a problem solution
  - What are the cultural, geographic, economic, etc. conditions
  - What are the various points of view & value judgment

Essential Elements of Analysis

- Holism & reductionism analysis must be done together
  - Determine the needs of the system and how each of these needs interact
  - Determine the needs of each domain within the system's and how each of these needs interact
  - Determine how to integrate the knowledge from each domain of the problem
  - Determine how to transfer knowledge among different domains
  - Determine the local and global patterns of the problem and solution
  - Define the measures that determine the solution effects on the system
  - Optimize the behavior of the individual components of the system
  - Optimize the behavior of the system
- Use of opposing views in problem evaluation
- Integration of knowledge of a problem and the constraints placed on the solution in order to optimize the solution
- Technology has consequences that should be anticipated & reduced or eliminated
- Technology should be viewed as an engagement not application

Essential Elements of Activities

- Students should use reflection of past experiences, successes, failures in order to anticipate future events
- Students should seek opposing views in problem evaluation process in order to better understand solution impacts
- Students should engage and evaluate of other students' work
- Encourage a critical dialogue among students

Table 2. Survey questions to assess changes in students' perception of engineering

Rate how difficult (not difficult to extremely difficult) you find each of the following topics Math, Physics, Chemistry, English-Composition, Classical Literature, Economics, Art, History, Political Science, Speech Communication, Biology, Social Scienced Psychology, Foreign Languages
Based on your current perception, indicate (no used to used all the time) if each of the following words are used when describing the characteristics of a successful engineer Cleaver, Engaging, Cautious, Excellent in Math, Indifferent, Narrow Interest, Ingenious, Reflective, Socially Disengaged, Empathetic, Egotistical, Resourceful, Collaborative, Guarded, Confident in Math Ability, Considerate, Adventurous, Inventive, Thoughtful, Knowledgeable of Other Cultures, Respectful, Modest, Uncreative, Ingenious, Reckless, Team-oriented, Enjoys Math Courses, Understanding, Multidisciplinary-oriented, Unconventional, Indifferent, Societal Sensitive, Imaginative, Individualistic
What is the level of importance (not important to extremely important) of following study areas do you believe an engineering student needs to solve this problem (outlined in the course) in a proper and satisfactory manner? Chemistry, Environmental Sciences, Human Development, Social Work, International policy making, Art History, Technology Sciences, Mathematics, Business Management, Mechanical design, Microbiology, Anthropology, Structural Sciences, History, Horticulture, The Performing Arts.

Table 3. Student responses to the question: Rate how difficult you find each of these topics. The survey was completed the first week and last week of the semester.

	Not difficult		Somewhat difficult		Difficult		Very difficult		Extremely difficult	
Topic	First week	Last week	First week	Last week	First week	Last week	First week	Last week	First week	Last week
Math	27%	40%	36%	40%	18%	20%	18%	0%	0%	0%
Physics	9%	10%	36%	30%	18%	50%	36%	0%	0%	10%
Chemistry	27%	0%	18%	20%	18%	40%	36%	30%	0%	10%
English-composition	36%	30%	18%	30%	45%	40%	0%	0%	0%	0%
Classical Literature	9%	20%	45%	30%	36%	40%	0%	10%	9%	0%
Economics	45%	30%	18%	50%	27%	20%	0%	0%	9%	0%
Art	18%	20%	45%	40%	36%	30%	0%	10%	0%	0%
History	45%	50%	36%	40%	9%	0%	9%	10%	0%	0%
Political Science	18%	20%	45%	60%	27%	20%	9%	0%	0%	0%
Speech Communications	27%	20%	45%	50%	27%	20%	0%	0%	0%	10%
Biology	27%	20%	45%	20%	27%	40%	0%	20%	0%	0%
Social Sciences	36%	20%	45%	70%	9%	10%	9%	0%	0%	0%
Psychology	36%	50%	36%	30%	27%	20%	0%	0%	0%	0%
Foreign Languages	9%	50%	55%	30%	9%	0%	18%	20%	9%	0%

Table 4. Students indicated if the following words characterized an engineer. The survey was completed the first week of the semester.

An engineer is	Not used	Sometimes Used	Used	Often Used	Used all of the time
Cleaver	0%	18%	27%	36%	18%
Engaging	0%	18%	45%	9%	27%
Cautious	0%	9%	18%	64%	9%
Excellent in math	0%	0%	0%	45%	55%
Indifferent	0%	36%	36%	18%	9%
Narrow in her/his interest	36%	36%	9%	18%	0%
Ingenious	0%	0%	45%	27%	27%
Reflective	0%	9%	36%	27%	27%
Socially disengaged	27%	36%	27%	9%	0%
Empathetic	0%	55%	27%	9%	9%
Egotistical	45%	36%	18%	0%	0%
Resourceful	0%	0%	36%	18%	45%
Collaborative	0%	0%	27%	36%	36%
Guarded	18%	18%	18%	36%	9%
Confident in math ability	0%	0%	0%	45%	55%
Considerate	0%	18%	27%	36%	18%
Adventurous	0%	18%	18%	36%	27%
Inventive	0%	0%	9%	64%	27%
Thoughtful	0%	9%	27%	27%	36%
Knowledgeable of other cultures	9%	27%	18%	18%	27%
Respectful	0%	18%	36%	18%	27%
Modest	0%	18%	45%	18%	18%
Uncreative	73%	18%	0%	9%	0%
Ingenious	0%	9%	27%	36%	27%
Team-oriented	0%	9%	9%	45%	36%
reckless	45%	55%	0%	0%	0%
Enjoys math courses	0%	0%	18%	64%	18%
Understanding	0%	9%	45%	36%	9%
Multidisciplinary-oriented	0%	0%	64%	27%	9%
Unconventional	18%	45%	27%	9%	0%
Indifferent	27%	27%	27%	18%	0%
Societal sensitive	0%	36%	27%	36%	0%
Imaginative	0%	9%	27%	36%	27%
Individualistic	9%	18%	36%	9%	27%

Table 5. Changes in students' responses that indicate words that characterize an engineer. Students completed the survey during the first week of the semester and again during the last week of the semester.

	Not used		Sometimes Used		Used		Often Used		Used all of the time	
	First week	Last week	First week	Last week	First week	Last week	First week	Last week	First week	Last week
Engaging	0%	0%	18%	10%	45%	10%	9%	50%	27%	30%
Indifferent	0%	40%	36%	30%	36%	20%	18%	10%	9%	0%
Socially disengaged	27%	60%	36%	10%	27%	10%	9%	10%	0%	10%
Empathetic	0%	10%	55%	20%	27%	40%	9%	20%	9%	10%
Understanding	0%	0%	9%	10%	45%	20%	36%	50%	9%	20%
Societal Sensitive	0%	10%	36%	10%	27%	50%	36%	20%	0%	10%
Individualistic	9%	30%	18%	30%	36%	10%	9%	20%	27%	10%
Excellent in math*	0%	0%	0%	0%	0%	30%	45%	30%	55%	40%

*included to show some responses did not change

Table 6. Students indicated which of the following areas of study are important for addressing the story line regarding the drought experienced by the university the students are attending. A summary of the responses provided at the beginning of the semester is shown.

Area of Study	Not important	Slightly important	Important	Very Important	Extremely Important
Chemistry	0%	0%	55%	45%	0%
Environmental Sciences	0%	18%	0%	55%	27%
Human Development	0%	18%	18%	45%	18%
Social work	18%	0%	18%	55%	9%
International Policy Making	9%	9%	36%	36%	9%
Art History	45%	45%	9%	0%	0%
Technology Sciences	0%	0%	27%	36%	36%
Mathematics	0%	0%	0%	36%	64%
Business Management	0%	9%	36%	36%	18%
Mechanical Design	0%	0%	9%	36%	55%
Microbiology	0%	27%	27%	45%	0%
Anthropology	9%	27%	64%	0%	0%
Structural Sciences	0%	18%	45%	9%	27%
History	18%	36%	0%	27%	18%
Horticulture	27%	27%	18%	18%	9%
The Performing Arts	55%	27%	0%	18%	0%

Table 7. Changes in students' responses that indicate words that characterize an engineer. Students completed the survey during the first week of the semester and again during the last week of the semester.

	Not important		Slightly important		Important		Very Important		Extremely Important	
	First week	Last week	First week	Last week	First week	Last week	First week	Last week	First week	Last week
Human Development	0%	0%	18%	0%	18%	50%	45%	30%	18%	20%
Technology Sciences	0%	0%	0%	0%	27%	50%	36%	10%	36%	40%
Mechanical Design	0%	0%	0%	10%	9%	30%	36%	10%	55%	50%
Anthropology	9%	20%	27%	10%	64%	40%	0%	20%	0%	10%
History	18%	10%	36%	10%	0%	20%	27%	40%	18%	20%